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(54) **THERMAL RECEIVER FOR HIGH POWER SOLAR CONCENTRATORS AND METHOD OF ASSEMBLY**

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See application file for complete search history.

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(51) **Int. Cl.**

H01L 31/052 (2014.01)

H01L 31/024 (2014.01)

(Continued)

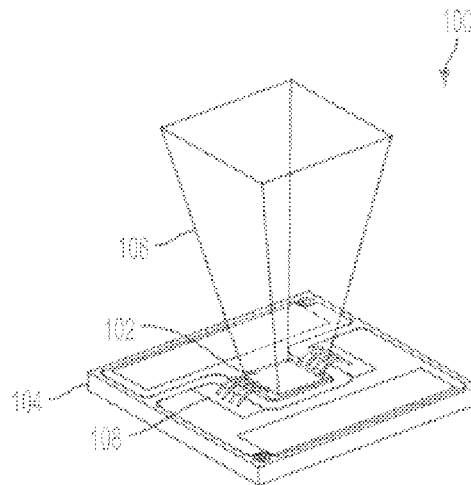
(52) **U.S. Cl.**

CPC *H01L 31/052* (2013.01); *H01L 31/024*

ABSTRACT

A device for dissipating heat from a photovoltaic cell is disclosed. A first thermally conductive layer receives heat from the photovoltaic cell and reduces a density of the received heat. A second thermally conductive layer conducts heat from the first thermally conductive layer to a surrounding environment. An electrically isolating layer thermally couples the first thermally conductive layer and the second thermally conductive layer.

17 Claims, 4 Drawing Sheets



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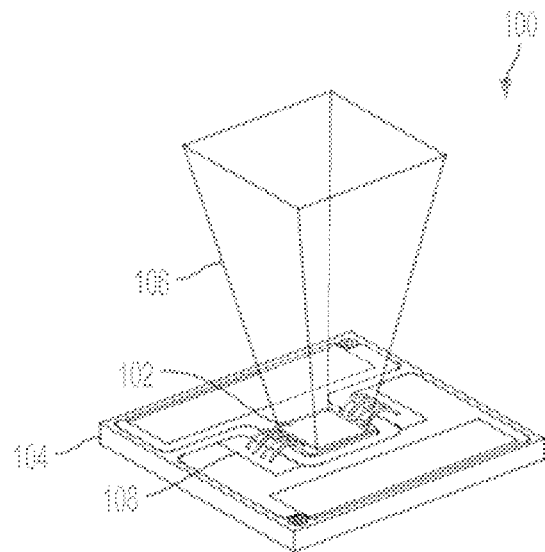


FIG. 1

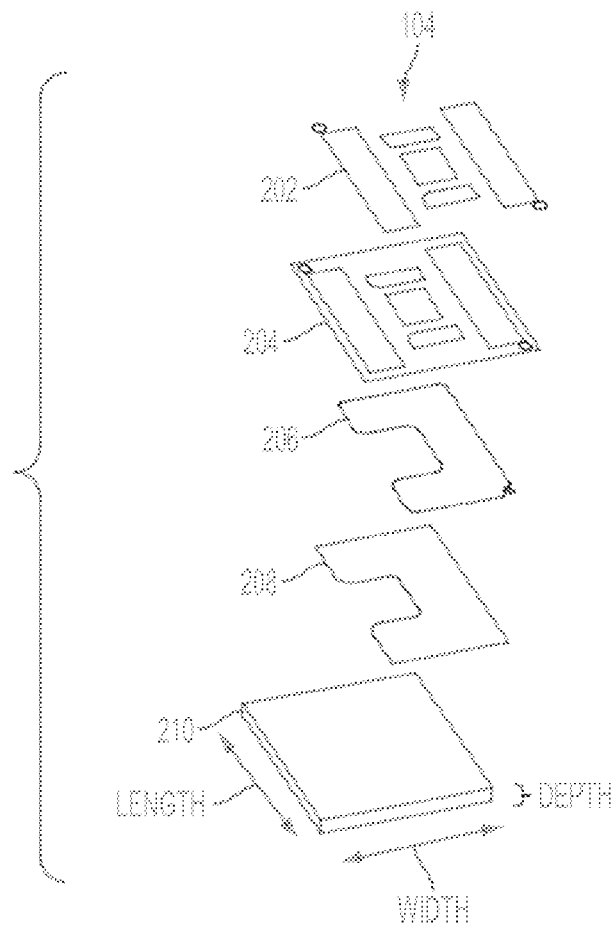


FIG. 2

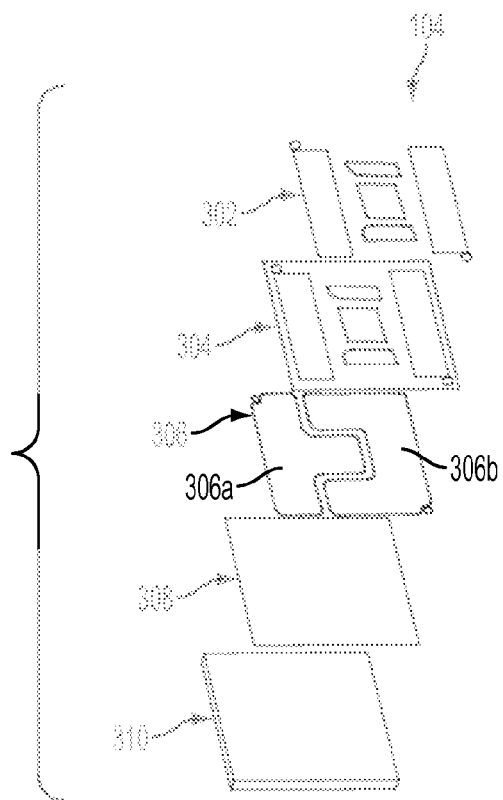


FIG. 3

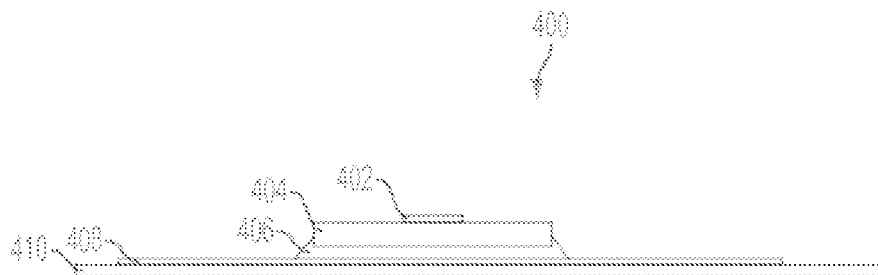


FIG. 4

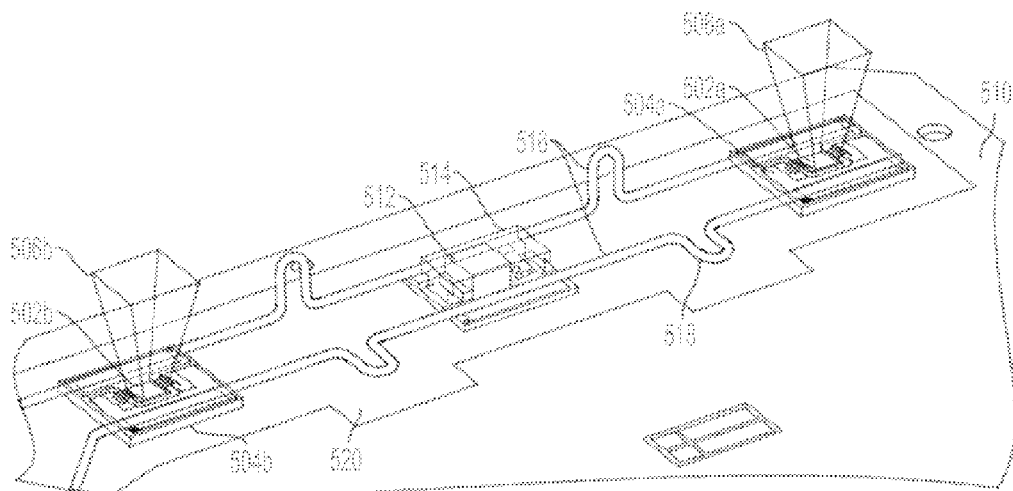


FIG. 5

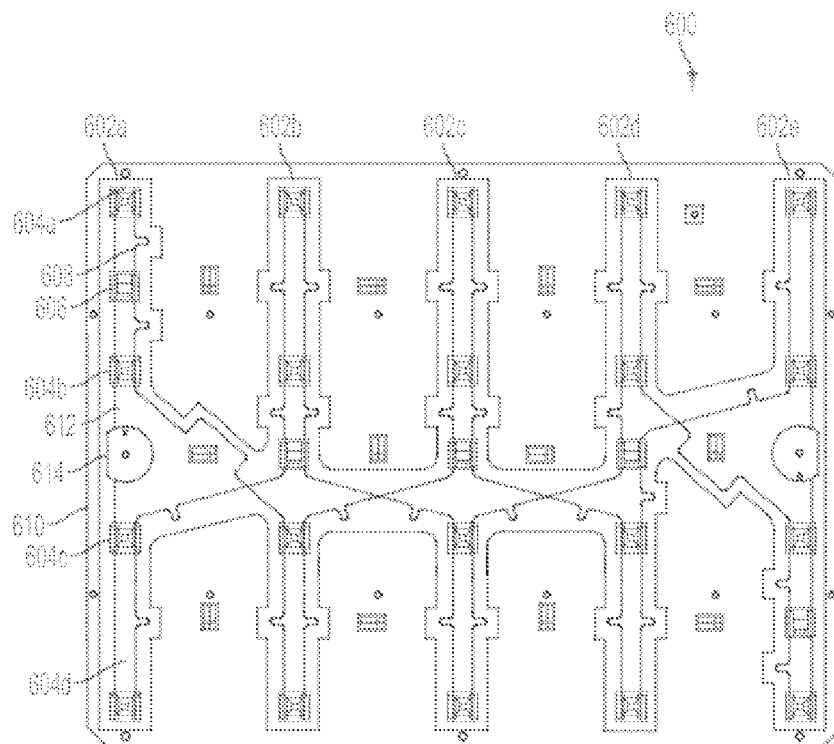


FIG. 6

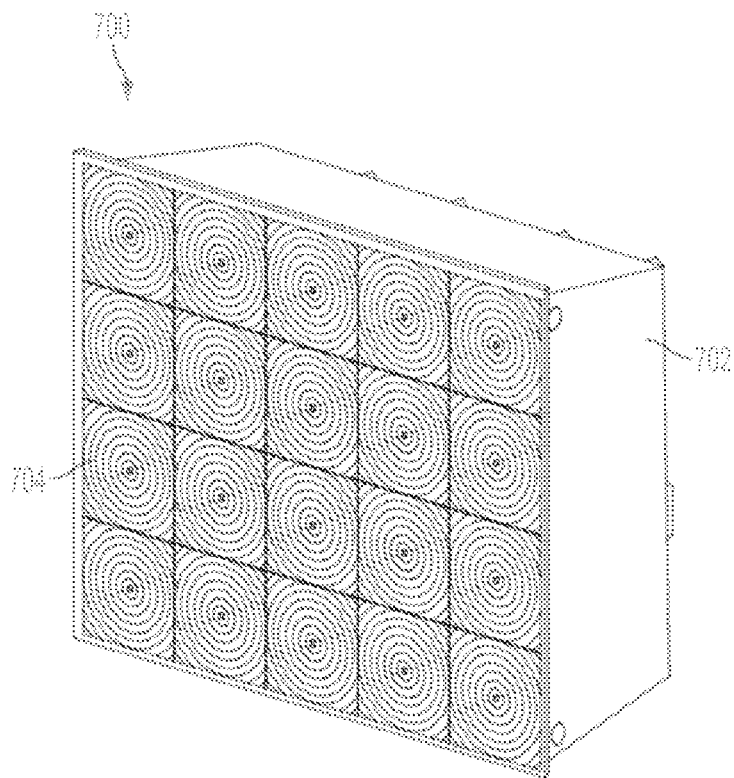


FIG. 7

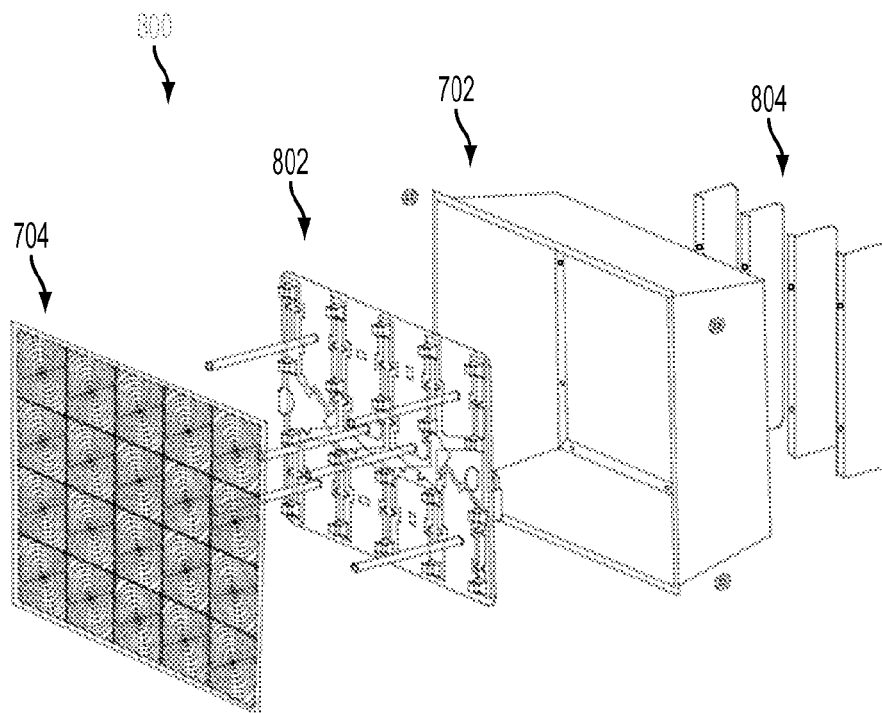


FIG. 8

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THERMAL RECEIVER FOR HIGH POWER SOLAR CONCENTRATORS AND METHOD OF ASSEMBLY

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 13/716,685, entitled "THERMAL RECEIVER FOR HIGH POWER SOLAR CONCENTRATORS AND METHOD OF ASSEMBLY", filed on Dec. 17, 2012, which is incorporated herein by reference in its entirety.

BACKGROUND

The present disclosure relates to solar energy, and more specifically, to dissipating heat from photovoltaic cells illuminated by concentrated solar rays.

Solar power concentrators are often used in photovoltaic systems to increase an output of the photovoltaic cells. New solar concentrators are able to increase a concentration of incident solar energy by up to and beyond 2000 times. A consequence of this concentration is the production of high levels of heat which raises the temperatures of solar cells. However, solar cells must be operated at temperatures that are typically less than about 110° C. in order to prevent heat damage. Another consequence of the solar concentration is a large current density. It is desired to couple this current to a load in a manner that offers as little electrical resistance as possible to avoid dissipating electrical energy as heat.

SUMMARY

According to one embodiment of the present disclosure, a device for dissipating heat from a photovoltaic cell includes: a first thermally conductive layer configured to receive heat from the photovoltaic cell and reduce a density of the received heat; a second thermally conductive layer configured to conduct heat from the first thermally conductive layer to a surrounding environment; and an electrically isolating layer configured to thermally couple the first thermally conductive layer and the second thermally conductive layer.

According to another embodiment of the present disclosure, a photovoltaic cell assembly includes: a photovoltaic cell; a first thermally conductive layer configured to receive heat from the photovoltaic cell and reduce a density of the received heat; a second thermally conductive layer configured to conduct heat from the first thermally conductive layer to a surrounding environment; and an electrically isolating layer configured to thermally couple the first thermally conductive layer and the second thermally conductive layer.

According to another embodiment of the present disclosure, a solar panel includes: a plurality of photovoltaic cell assemblies; at least one wire coupling the photovoltaic cell assemblies; wherein a photovoltaic cell assembly selected from the plurality of photovoltaic cell assemblies includes: a photovoltaic cell, a first thermally conductive layer configured to receive heat from the photovoltaic cell and reduce a density of the received heat, a second thermally conductive layer configured to conduct heat from the first thermally conductive layer to a surrounding environment, and an electrically isolating layer configured to thermally couple the first thermally conductive layer and the second thermally conductive layer.

Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail herein and

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are considered a part of the claimed disclosure. For a better understanding of the disclosure with the advantages and the features, refer to the description and to the drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The subject matter which is regarded as the disclosure is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The forgoing and other features, and advantages of the disclosure are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 shows a photovoltaic assembly according to an exemplary embodiment of the present disclosure;

FIG. 2 shows an exploded view of an exemplary cell package of the photovoltaic assembly FIG. 1 in one embodiment of the present disclosure;

FIG. 3 shows an alternate embodiment of a cell package of the photovoltaic assembly of FIG. 1;

FIG. 4 shows a cross-sectional view of an exemplary photovoltaic assembly coupled to a backplane;

FIG. 5 shows an exemplary assembly for mounting a plurality of photovoltaic assemblies;

FIG. 6 shows a top view of a solar panel assembly in an exemplary embodiment;

FIG. 7 shows an exemplary solar panel package of the present disclosure; and

FIG. 8 shows an exploded view of the solar panel package of FIG. 7.

DETAILED DESCRIPTION

FIG. 1 shows a photovoltaic assembly 100 according to an exemplary embodiment of the present disclosure. The exemplary photovoltaic assembly 100 includes an optical assembly 106 that is affixed to a front surface of a photovoltaic cell 102 for concentrating solar rays. In an exemplary embodiment, the optical assembly 106 provides a concentration of about 1600 times or greater than the incident solar concentration. In an exemplary embodiment, this level of solar concentration produces a large amount of heating at the photovoltaic cell 102. The photovoltaic cell 102 is coupled to a cell package 104 for dissipating heat from the photovoltaic cell 102. In an exemplary embodiment, a back surface of the photovoltaic cell 102 is directly soldered to the cell package 104 using a solder. The solder may include an 80/20 lead/tin solder or a low melt solder. Alternate solders usable for soldering the photovoltaic cell 102 and cell package 104 may include alloys containing at least one of lead, tin, copper, gallium, silver, manganese, magnesium, bismuth, indium, zinc and antimony, such as for example Sn—Ag—Cu, Sn—Ag—Cu—Zn and Sn—Ag—Cu—Mn. Alternately, the photovoltaic cell 102 may be coupled to the cell assembly 104 using a conductive particle infused polymer adhesive, such as silver paste. Wires 108 are bonded between the photovoltaic cell 102 and the cell package 104 to provide an electrical path for current produced at the photovoltaic cell 102. In an exemplary embodiment, the wires 108 may be bonded using a solder such as the exemplary solders listed above. In an alternate embodiment the cell is connected to the top surface conductors on the cell package using one of wire bonding and ribbon bonding methods where the wire and ribbon may comprise one of gold, silver, platinum, palladium, aluminum, silicon and copper.

FIG. 2 shows an exploded view of an exemplary cell package 104 of FIG. 1 in one embodiment of the present disclosure.

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sure. The exemplary cell package **104** includes a coating **202**, a solder mask **204**, a copper layer **206**, a dielectric layer **208** and a substrate layer **210**. In an exemplary embodiment, copper layer **206** and substrate layer **210** form electrodes coupled to the photovoltaic cell **102**. In an exemplary embodiment, copper layer **206** forms an electrical circuit with the photovoltaic cell **102**.

Coating **202** provides a top surface of the cell package and is in contact with the photovoltaic cell **102**. Coating **202** provides a substantially corrosion resistant surface for wire bonding and may include at least one of gold, silver, nickel, zinc and tin. Solder mask **204** provides a second layer of the cell package **104** and includes an insulating material. The solder mask may include standard solder mask material such as, for example, an epoxy paint. The solder mask **204** may be applied via screen printing in an exemplary embodiment. The solder mask may have windows for wire bonding, strap bonding or strap welding of connections between the photovoltaic cell **102** and package electrodes (not shown) of the cell package **104**. The solder mask **204** further includes windows allowing interconnecting wires (see FIG. 5) to be soldered to the package electrodes, thereby interconnecting a plurality of photovoltaic assemblies **100** to each other and/or to an external device. In exemplary embodiments, the interconnecting wires may be bonded between the photovoltaic cell **102** and the electrodes of the cell package **104** using gold wire bonding, ribbon bonding or strap welding, for example. Connective bonding material may include at least one of gold, silver, Invar, iron, copper and tin.

Copper layer **206** provides a third layer of the cell package **104** and is an electrically conductive layer that forms a second electrode of the photovoltaic cell **104**. In alternate embodiments, the copper layer **206** may be made of any material that is electrically conductive. Copper layer **206** may be patterned using exemplary lithographic methods such as photolithography, screen printing, and ink jet printing, for example. After patterning, an etch process may be used to remove unwanted copper from the copper layer **206** to form a selected shape. In addition, the copper layer is selected to provide an electrically conductive channel for conducting current generated from the photovoltaic cell, for example, to the interconnecting wires. In various embodiments, the current densities are in a range from about 6.3 amps per square centimeter (amps/cm²) to about 25.2 amp/cm². The copper layer **206** may be electrically coupled to an electrode of the photovoltaic cell **102** using a ribbon bond, a wire bond, etc.

Dielectric layer **208** provides a fourth layer of the cell package **104** that provides electrical isolation of the copper layer **206** from the underlying substrate layer **210**. The dielectric layer **208** further allows heat transfer from the copper layer **206** to the substrate layer **210**. In an exemplary embodiment, the dielectric layer **208** may include an FR4 matrix of glass fiber and epoxy that may be cured by thermal, chemical or ultraviolet methods.

Substrate layer **210** provides a fifth and bottom layer of the cell package **104** and may be a thick layer in comparison to layers **202-208**. The substrate layer **210** may serve as both an electrode and a thermal conductor. Increasing the thickness of the substrate layer **210** relative to the thicknesses of layers **202-208** increases an ability of the substrate layer **210** to spread the heat conducted to the substrate layer from the photovoltaic cell **104** via the layers **202-208**. The substrate layer may have lateral dimensions of length and width. Increasing the size of the lateral dimensions may improve a thermal coupling of the substrate layer **210** to a backplane (see FIG. 4). The lateral dimension and thickness of the substrate layer may be selected to achieve a selected thermal

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performance (i.e., solar heat dissipation) of the cell package **104** and a selected operating temperature of the related photovoltaic assembly **100**. In an exemplary embodiment, the substrate layer **210** is made of copper or other material selected to achieve high thermal conductivity. In alternate embodiments, layer **210** may include aluminum or at least one of copper, aluminum, iron, chrome, nickel, molybdenum, zinc and tin. In an embodiment in which a photovoltaic cell has a length and width of about 3.75 millimeters (mm), a length and width of the substrate layer **210** may be about 15 mm and the thickness may be about 1.5 mm.

Layers **206**, **208** and **210** may be coupled to each other by pressure and heat to cure layer **208** to form a bond. In an exemplary embodiment, layers **206**, **208** and **210** may be bonded to form a sheet that is then separated into individual substrates suitable for use in a selected cell package **104**. The separated substrates may be patterned into individual substrate layers using printed circuit methods.

FIG. 3 shows a cell package **104** in an alternate embodiment. The alternate cell package **104** includes a coating **302**, a solder mask **304**, a copper layer **306**, a dielectric layer **308** and a substrate layer **310**. In the alternate embodiment, layer **306** includes both cell electrodes **306a** and **306b** coupled to the photovoltaic cell **102** and is made of thick copper that has a thickness that is substantially between about 20 microns and about 400 microns. The dimensions of the layer **306** are selected so as to be conducive to spreading heat laterally. Layer **308** is made thin in comparison to layer **208** of FIG. 2 to increase heat transfer between layer **306** and the substrate **310**.

FIG. 4 shows a cross-sectional view **400** of an exemplary photovoltaic assembly coupled to a backplane **410**. The photovoltaic assembly includes photovoltaic cell **402** mounted on an exemplary cell package **404**. The cell package **404** is coupled to an insulation layer or layers **408** via a thermal adhesive **406** that allows heat transfer between the cell package **404** and the insulation layer or layers **408**. The insulation layer or layers **408** may be a printable layer. In one embodiment, the insulation layer or layers **408** may be multi-layer insulators. The insulation layer or layer **408** may also include aluminum oxide, polymers, or other electrically resistive particles, etc.

In an exemplary embodiment, the thermal adhesive **406** may include a material having at least one of a high thermal conductivity, a high mechanical flexibility, an ability to cure at low temperatures, an ability to withstand operating temperatures in a range from about -40° C. to about 120° C., and an ability to adhere to the contacting faces of the cell package **404** and of the insulation layer or layers **408** providing electrical insulation. The thermal adhesive **406** may include, but is not limited to, SilCool™ TIA-0220 of Momentive Performance Materials, Inc. In an exemplary embodiment, the thermal adhesive **406** includes an insulating silicone adhesive. In alternate embodiments, the thermal adhesive **406** may include epoxy and acrylic adhesives. In another embodiment, the thermal adhesive **406** includes a polymer with thermally conductive particles embedded therein. Exemplary polymers may include at least one of silicone, acrylic and epoxy. Exemplary particles may include at least one of aluminum oxide, aluminum nitride and silicon dioxide. In an exemplary embodiment, the thermal adhesive **406** is compressed to a thin bond line of approximately 50 microns or less and is allowed to slightly extrude beyond the edges of the cell package **404**.

The insulation layer **408** or layers reduces electrical conduction between the cell package **404** and the backplane **410**, while allowing heat transfer therebetween. The insulation layer or layers **408** may be bonded to an aluminum backplane

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410 prior to bonding the insulation layer or layers 408 to the cell package 404. The insulation layer or layers 408 may include an epoxy-based screen-printable material. In various embodiments, the insulation layer or layers 408 may include any electrically-insulating material with high dielectric strength, strong adhesion to the anodized aluminum of the backplane 410 and an ability to resist heat damage at temperatures in an operating range from about 85° C. to about 120° C. In an exemplary embodiment, the insulation layer or layers 408 may include TechniFlex by Technic Corp. and may be applied using screen printing methods on the backplane 410 to a thickness of about 15 microns. In alternative embodiments, the insulation layer or layers 408 may include, but is not limited to, paints, lacquers, powder coats, etc. Such materials in the alternative embodiment of the insulation layer or layers 408 may include at least one of polyester, polyurethane, polyester-epoxy, epoxy, acrylic and silicone.

The aluminum backplane 410 may include a sheet of anodized aluminum. In an exemplary embodiment, the backplane 410 includes a sheet of about 1.5 mm in thickness and an anodized layer thickness of about 10 microns. In various embodiments, the anodized layer may have a thickness that provides a protective layer to the aluminum surface as well as an electrical breakdown resistance. Electrical breakdown resistance is provided by the thermal adhesive 406, the insulation layer or layers 408 and the anodization of the backplane 410.

In an exemplary operation of the photovoltaic assembly, heat concentrated at the photovoltaic cell is transferred to the cell package 404. At the cell package 404, the heat is distributed in along lateral dimensions of the cell package at the copper substrate, such as substrate 210 in FIGS. 2 or alternately substrate 310 in FIG. 3 in order to reduce an areal density of the heat by spreading the heat, in general along a lateral dimension of the substrate. Heat from the substrate 210 is transferred to the aluminum backplane 410 through the insulation layer 408. In various embodiments, the insulation layer 408 prevents current transfer between substrate 310 and the aluminum backplane 410 by providing a breakdown resistance to about 1700 volts or more.

FIG. 5 shows an exemplary assembly 500 for mounting a plurality of photovoltaic assemblies. Cell package 502a is shown having an associated photovoltaic cell 504a and an associated secondary optic 506a. Cell package 502b is shown having an associated photovoltaic cell 504b and an associated secondary optic 506b. Cell packages 502a and 502b are coupled to the aluminum backplane 510 via exemplary screen-printed dielectric 520. Cell packages 502a and 502b are disposed on the backplane 510 at a location that corresponds to a focal point of their respective secondary optics 506a and 506b when the backplane 501 is perpendicular to solar radiation. In one embodiment, a protection diode 512 is packaged to the backplane in a manner similar to the packaging of cell packages 502a and 502b. The protection diode 512 includes a heat shield 514 that protects the protection diode 512 from heat or dissipates heat from the protection diode 512. In an exemplary embodiment, the heat shield 514 includes a copper strip that covers the protection diode 512 and is soldered to contact pads of the diode package.

Interconnecting wiring 516 provides an electrical connection between cell packages 502a and 502b. In one embodiment, the interconnecting wiring 516 connects printed circuit layers of the cell packages 502a and 502b. The interconnecting wiring 516 includes copper wire that is soldered to electrodes of the cell packages 502a and 502b. The diameter of the wire is selected to handle a current provided by the exemplary cell packages and to reduce internal resistance losses.

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Kinks 518 are introduced into the interconnecting wiring 516 to avoid mechanical stress due to thermal expansion of the interconnecting wiring 516. The interconnecting wiring 516 may be sufficiently rigid to be self-supporting. The interconnecting wiring 516 may be affixed to the backplane 510 separated by a separation distance in a range of about 1 millimeter to about 2 millimeters above the surface of the backplane 510. Such a configuration avoids physical contact with the insulating dielectric or with the aluminum anodized surface.

FIG. 6 shows a top view of a solar panel assembly 600 in an exemplary embodiment. The exemplary solar panel assembly 600 includes five tiers 602a-602e of cell packages. In each tier, four cell packages, such as exemplary cell packages 604a-604d, and a protection diode 606 are connected in parallel using the interconnecting wiring 608. The cell packages are coupled to an aluminum backplane 610 via dielectric layer 612. The tiers 602a-602e are connected in series to form a solar panel assembly 600 having 20 cell packages. In various embodiments, the number of cells in parallel vs. the number of cells in series may be selected to achieve a selected current-voltage ratio of the solar panel assembly 600. Having cells wired in parallel (in the tiers) allows one or more cells to fail while maintaining the function of the panel at a reduced power, thereby improving an overall reliability of the solar panel assembly 600. Terminal connections 614 provide electrical coupling from the interconnecting wiring 608 to external circuitry. The interconnect wiring 608 may be soldered to an insulated multi-strand copper external connection wire (not shown) that penetrates the aluminum backplane 610 to an exterior of the solar panel assembly 600 via a strain relief cord grip.

FIG. 7 shows an exemplary solar panel package 700 of the present disclosure. The exemplary solar panel package 700 includes an enclosure 702 that encloses a solar panel assembly (not shown) having one or more cell packages according to the present disclosure. A lens 704 such as a Fresnel lens is coupled to a top of the enclosure 702 using an adhesive, to enclose the solar panel assembly. In various embodiments, the adhesive includes a silicone adhesive. Filtered vents are provided in the enclosure 702 to equalize pressures between an interior and an exterior of the enclosure 702 and to allow moisture within the enclosure to escape to an exterior of the enclosure 702.

FIG. 8 shows an exploded view 800 of the solar panel package 700 of FIG. 7. The exploded view 800 shows the enclosure 702 and the Fresnel lens 804. Additionally, the exploded view 800 shows the solar panel assembly 802 that includes a number of cell packages and resides in a chamber formed by the enclosure 702 and the Fresnel lens 704. The enclosure 702 may further include one or more cooling fins 804 to aid in the dispersion of heat from the enclosure 802 and thus from the solar panel 802.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one more other features, integers, steps, operations, element components, and/or groups thereof.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act

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for performing the function in combination with other claimed elements as specifically claimed. The description of the present disclosure has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the disclosure in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the disclosure. The embodiment was chosen and described in order to best explain the principles of the disclosure and the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

The flow diagrams depicted herein are just one example. There may be many variations to this diagram or the steps (or operations) described therein without departing from the spirit of the disclosure. For instance, the steps may be performed in a differing order or steps may be added, deleted or modified. All of these variations are considered a part of the claimed disclosure.

While the exemplary embodiment to the disclosure had been described, it will be understood that those skilled in the art, both now and in the future, may make various improvements and enhancements which fall within the scope of the claims which follow. These claims should be construed to maintain the proper protection for the disclosure first described.

What is claimed is:

1. A device for dissipating heat from a photovoltaic cell, comprising:
 - a coating layer in contact with the photovoltaic cell;
 - a first thermally conductive layer configured to receive heat from the photovoltaic cell and reduce a density of the received heat;
 - a solder mask between the coating layer and the first thermally conductive layer;
 - a second thermally conductive layer configured to conduct heat from the first thermally conductive layer to a surrounding environment;
 - an electrically isolating layer configured to thermally couple the first thermally conductive layer and the second thermally conductive layer;
 - a thermal adhesive layer coupled to the second thermally conductive layer;
 - an electrically insulating layer coupled to the thermal adhesive layer; and
 - a thermally conducting backplane coupled to the second thermally conductive layer.
2. The device of claim 1, wherein the first thermally conductive layer is configured to reduce the heat density by spreading heat over a lateral area.
3. The device of claim 1, wherein the first thermally conductive layer is further configured to conduct electricity from the photovoltaic cell.
4. The device of claim 1, wherein the first thermally conductive layer further comprises at least one of copper and aluminum, iron, chrome, nickel, molybdenum, zinc, silver, gold and tin.
5. The device of claim 1, wherein the first thermally conductive layer and second thermally conductive layer are configured to maintain an operating temperature of the photovoltaic cell at or below about 110° C.
6. The device of claim 1, wherein the first thermally conductive layer, second thermally conductive layer and electrically isolating layer are configured to prevent an electrical breakdown at a voltage up to about 1700 volts.

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7. A photovoltaic cell assembly, comprising:
 - a photovoltaic cell;
 - a coating layer in contact with the photovoltaic cell;
 - a first thermally conductive layer configured to receive heat from the photovoltaic cell and reduce a density of the received heat;
 - a solder mask between the coating layer and the first thermally conductive layer;
 - a second thermally conductive layer configured to conduct heat from the first thermally conductive layer to a surrounding environment;
 - an electrically isolating layer configured to thermally couple the first thermally conductive layer and the second thermally conductive layer;
 - a thermal adhesive layer coupled to the second thermally conductive layer;
 - an electrically insulating layer coupled to the thermal adhesive layer; and
 - a thermally conducting backplane coupled to the second thermally conductive layer.
8. The assembly of claim 7 further comprising a solar concentrator configured to concentrate solar rays at the photovoltaic cell.
9. The assembly of claim 7, wherein the first thermally conductive layer is configured to reduce the heat density by spreading heat received from the photovoltaic cell over a lateral area.
10. The assembly of claim 7, wherein the first thermally conductive layer further comprises a printed circuit layer electrically coupled to an electrode of the photovoltaic cell.
11. The assembly of claim 10, wherein the printed circuit layer is electrically coupled to the electrode of the photovoltaic cell via at least one of: a ribbon bond and a wire bond.
12. The assembly of claim 10 further comprising a wire configured to couple the printed circuit layer to another photovoltaic cell assembly.
13. The assembly of claim 7, wherein the first thermally conductive layer further comprises at least one of copper and aluminum, iron, chrome, nickel, molybdenum, zinc, silver, gold and tin.
14. A solar panel, comprising:
 - a plurality of photovoltaic cell assemblies;
 - at least one wire coupling the photovoltaic cell assemblies;
 - wherein a photovoltaic cell assembly selected from the plurality of photovoltaic cell assemblies includes:
 - a photovoltaic cell;
 - a coating layer in contact with the photovoltaic cell;
 - a first thermally conductive layer configured to receive heat from the photovoltaic cell and reduce a density of the received heat;
 - a solder mask between the coating layer and the first thermally conductive layer;
 - a second thermally conductive layer configured to conduct heat from the first thermally conductive layer to a surrounding environment;
 - an electrically isolating layer configured to thermally couple the first thermally conductive layer and the second thermally conductive layer;
 - a thermal adhesive layer coupled to the second thermally conductive layer;
 - an electrically insulating layer coupled to the thermal adhesive layer; and
 - a thermally conducting backplane coupled to the second thermally conductive layer.
15. The solar panel of claim 14 wherein a number of photovoltaic cells connected in series and in parallel by the wire is selected to achieve a selected current/voltage ratio.

16. The solar panel of claim **14** further comprising at least one fin configured to draw heat from the backplane.

17. The solar panel of claim **14** further comprising an enclosure of the solar panel that includes a Fresnel lens.

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